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INFORMAL REPORT

TEST AND EVALUATION OF A SPAR-TYPE OCEANOGRAPHIC BUOY

JULY 1969

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

INFORMAL REPORT

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ABSTRACT

This report discusses the sea test and evaluation of a modified spar, taut-moored oceanographic/meteorologic buoy. The Litton buoy was implanted during January 1969 in 12,600 feet of water approximately twenty-five miles southwest of Bermuda. This test was terminated after three weeks when the buoy parted its moor at the sensor cable bell-mouthed housing. Detailed information covers implantment and retrieval techniques, environmental endurance, and overall system effectiveness. The major buoy structural deficiencies are documented and analyzed. Although the taut-moored concept shows promise, failure of the oceanographic sensor cable end termination remains a formidable problem.

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Oceanographic Prediction Division

This report has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.

R J McGough
Division Director

CONTENTS

I. BACKGROUND

Litton Industries designed and fabricated two oceanographic/meteorologic buoys under a U.S. Naval Oceanographic Office contract. Preliminary field acceptance tests were conducted in 1,780 feet of water off Freeport, Grand Bahamas, during June 1966. This test was terminated twenty-four days after implantment by failure of the mooring at the bell-mouthed housing (mechanical interface between sensor cable and buoy). Since failure of the mooring was the only major structural weakness uncovered during the preliminary sea trial, the Naval Oceanographic Office accepted the basic buoy design and concentrated on redesign of the bell-mouthed housing for future tests.

II. PHYSICAL CHARACTERISTICS OF LITTON BUOY

A. General

The Litton buoy (figure 1) is an unattended data collection and telemetry station designed for deepwater application. Oceanographic sensors measure water temperature and water pressure from surface to 1,000 feet; meteorologic sensors record wind speed, wind direction, air temperature, and barometric pressure. All data are recorded and transmitted in standard teletype format via an HF telemetry link to receiving stations at distances to 1,000 miles.

B. Mechanical Description of Buoy Hull

The buoy assembly (figure 2) consists of an aluminum float (15-foot length, 5.5-foot diameter), a damping disc/battery housing (10-foot diameter), and an interconnecting spar (26-foot length, 1.5-foot diameter). An 8-foot instrument mast, which supports a 16-foot marine antenna, is affixed to the upper buoy body. The overall buoy length, not including the antenna, is 49 feet. The buoy weighs approximately 10,000 pounds and has a total reserve buoyancy of 20,000 pounds.

C. Mooring System

The mooring (figure 3) consists of a 1,000-foot sensor cable, a 1,000-foot fish-bite cable, a section of eight-plaited nylon line, and an anchor chain and anchor. The mooring is a taut-line arrangement with a scope (line length to depth ratio) of 0.8. Two acoustic release mechanisms are provided for retrieval purposes.

The oceanographic sensor cable is constructed of 0.84-inch-diameter, triple armor, improved plow steel, and contains eight electrical conductors. In effect, the armor is the strain carrying member and the inner core consists of the conductors. Minimum breaking strength is about 74,000 pounds. Sensor breakouts are made in special "bird cages" at twenty-one locations along the cable, with spacings ranging from 20 to 100 feet. Thermistors are incorporated within each bird cage; pressure transducers are located at the 100-, 500-, and 1,000-foot levels.

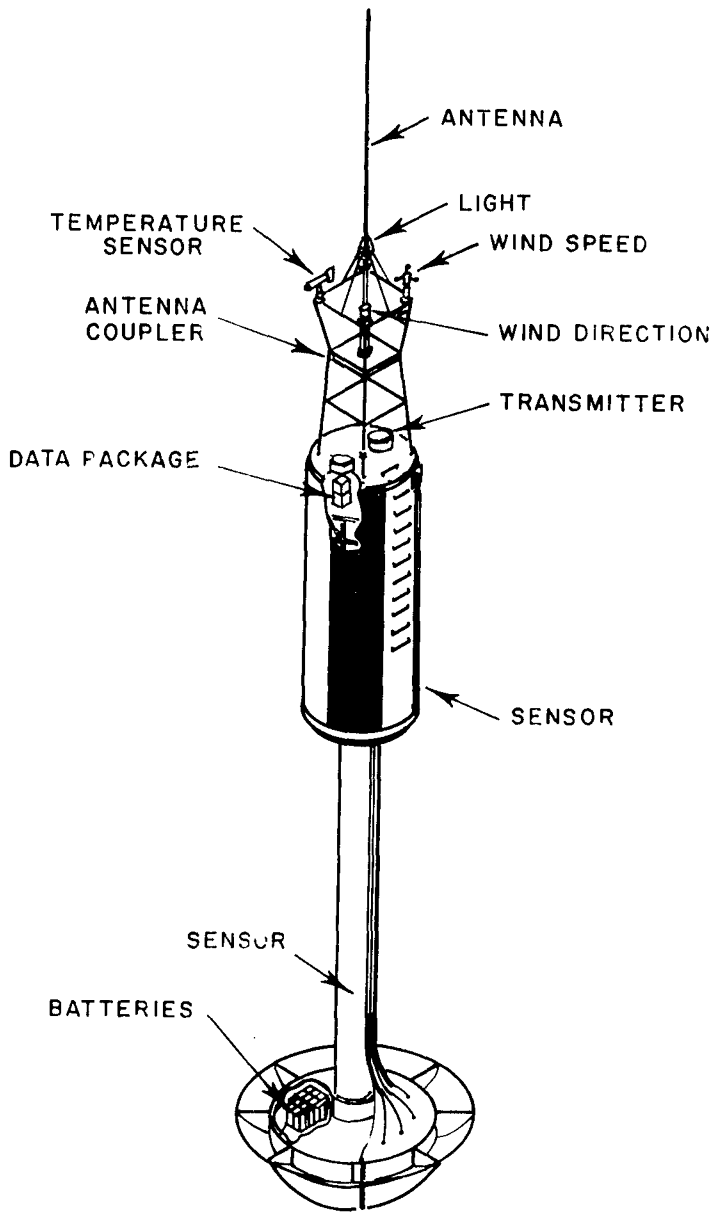

FIGURE I DEEP MOORED TELEMETERING OCEANOGRAPHIC/METEOROLOGICAL BUOY

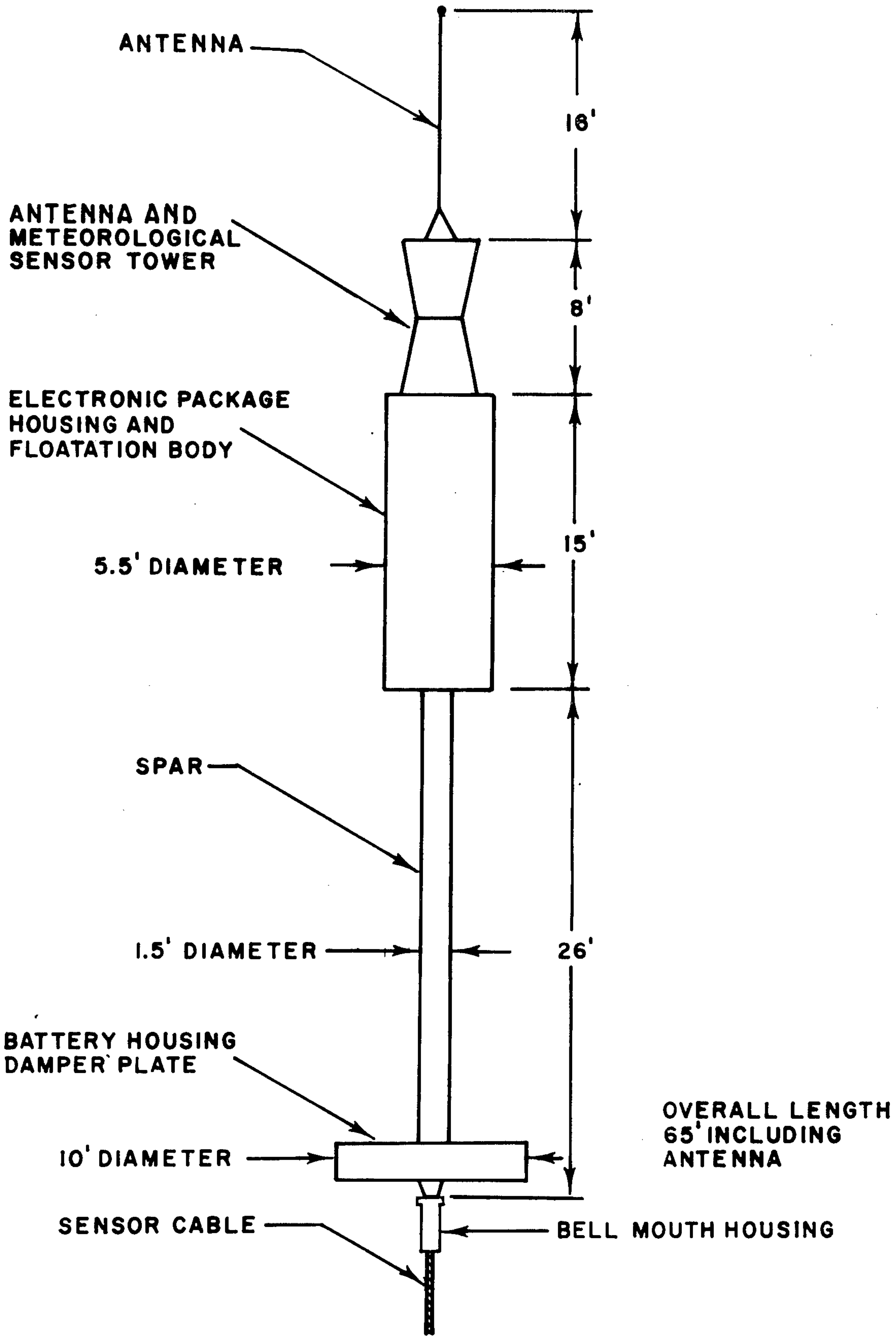

FIGURE 2 LITTON BUOY DIMENSIONAL ENVELOPE

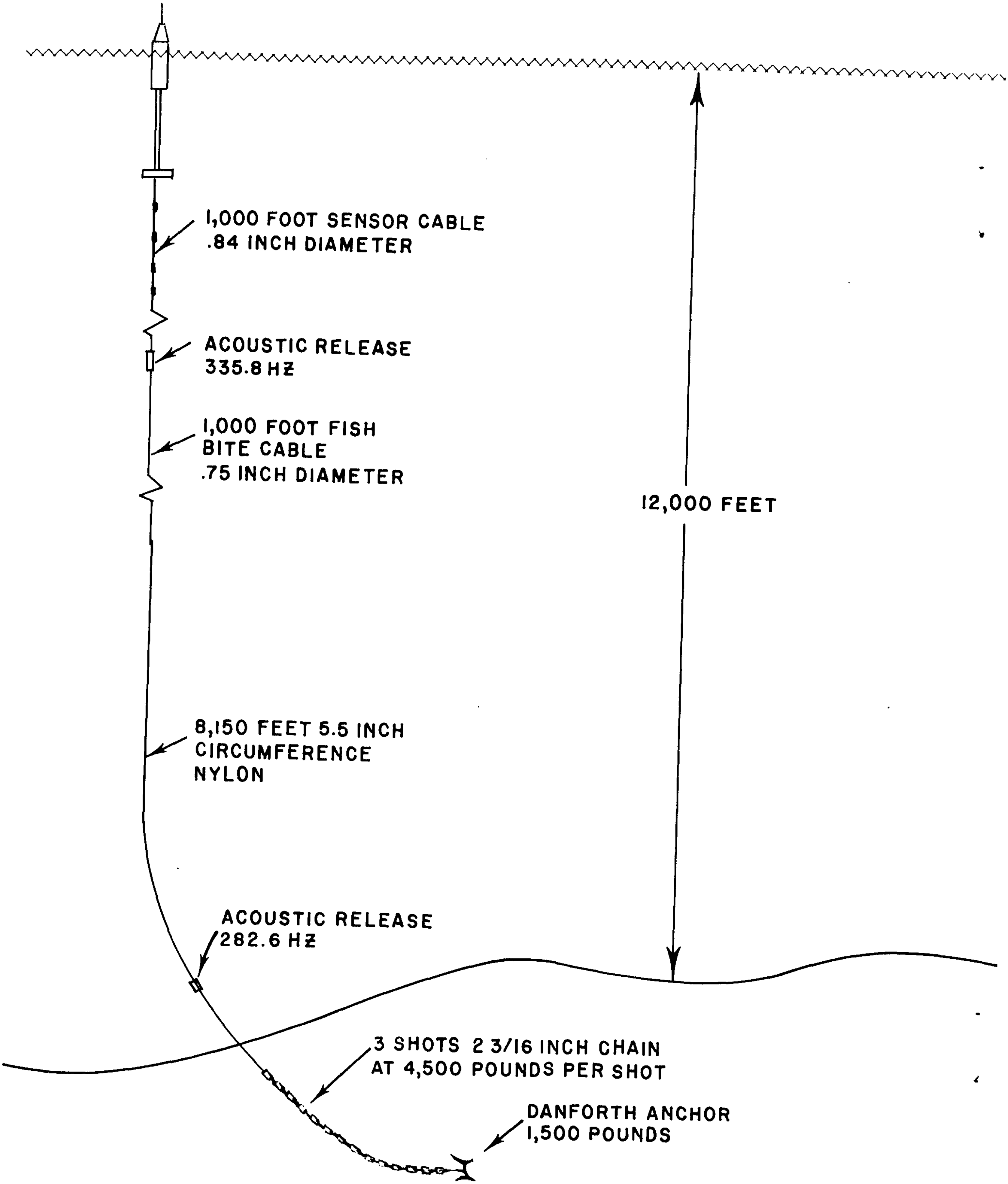

FIGURE 3 MOORING CONFIGURATION

The length of nylon line utilized in the mooring is derived from a percent elongation - percent ultimate strength curve to provide the proper mooring tension and scope. The nylon line has a circumference of 5 inches and a breaking strength of 70,000 pounds.

D. Telemetry Subsystem

Data from four meteorologic and twenty-one oceanographic sensors were telemetered over a standard 100-word-per-minute radioteletype circuit. Daytime and nighttime capability is provided with automatic frequency switching between 4 MHz and 8 MHz. The 500-watt telemetry package can be programmed to transmit at 3-, 6-, 12-, or 24-hour intervals. Power is supplied by a bank of lead-acid storage batteries housed in the damping disc. Forty-eight Willard DHB-5 batteries produce 48,000 watt-hours, sufficient power for system operation of six months before battery charging is required, assuming a 6-hour cycling period.

E. Data Package Subsystem

This instrumentation subsystem controls the transmission schedule, sensor selection, conversion of analog sensor outputs to digital data, and formatting of the data (appendix A) for transmission as readable teletype message. The data from the oceanographic/meteorological sensors as well as instrumentation monitoring check points, such as primary battery voltage and forward and reflected transmitter power, are monitored.

F. Litton Design Philosophy

In essence, Litton Industries' design criteria/philosophy in selecting the taut-moor modified spar concept was twofold: (1) to partially decouple the buoy from surface forcing functions, so that the rate of displacement change in a wave is reduced enough to limit the acceleration on the line mass (inertial reaction), and (2) to induce a minimum profile drag area by means of rigid, nearly vertical mooring. Basically, criterion (1) is accomplished by means of a disc incorporating a circumferential cavity which performs as a high drag spoiler to reduce upward vertical acceleration. From Newton's Law, $f=ma$, it can readily be seen that dynamic mooring loads are minimized by acceleration control. Criterion (2) is accomplished by the taut-moor system which reduces current velocity drag component on the short taut line. Since the line would assume a near vertical attitude, the water mass acceleration immediately forward of the mooring line would also be minimized.

III. IMPLANTMENT AND RETRIEVAL

A. Optimizing Buoy Implantment Techniques

A major foreseen problem involved implantment techniques from a Coast Guard buoy tender (USCGC CACTUS). It was envisioned that transferral from the CACTUS deck (50 x 36 feet) into the water would be difficult in light of the following buoy physical characteristics:

1. Total length with antenna is 65 feet.

2. Buoy angle of less than 13° with the horizontal may result in battery acid spillage.

3. Vulnerability of the interconnecting spar to bending stresses during implantment.

Thus, the CACTUS conducted a preliminary handling exercise using the buoy hull. Several methods were tried, and the "double purchase technique" was the most satisfactory. This plan consisted of stowing the buoy in a fore-and-aft direction with the CACTUS boom whip and main lines secured to the buoy body and damping disc, respectively (figure 4). The buoy would be lowered into the water with the 2-point suspension, followed by deployment of the mooring and ground tackle assembly. In effect, this would be a buoy-first anchor-last implantment. Hydrodynamic calculations for the buoy confirmed that stresses incurred during anchor freefall would not be excessive.

B. Implantment Location

A location approximately nine miles from ARGUS ISLAND, an oceanographic research tower near Bermuda, was selected as the implantment site (figure 5). Frequent visual observations, oceanographic/meteorologic real-time comparisons, and minor on-site repairs might be conducted on the buoy because of the proximity to Bermuda. In addition, the bottom contour gradient near Plantagenet Bank, on which ARGUS ISLAND is located, is favorable for a freefall anchor-last implant. Other good features of the location included distance from heavy shipping lanes, weak currents, and ready access to staging facilities.

C. Implantment

The U.S. Naval Oceanographic Office coordinated field test operations; the Coast Guard (USCGC CACTUS) performed the implantment. Naval Operating Base, Bermuda, was used as the staging area for preparation of the buoy and mooring, system troubleshooting and checkout, and calibration of oceanographic/meteorologic sensors. Prior to implantment the CACTUS conducted wind drift and current drift studies and fathometer confirmation on the implant site, a 2.5- by 6-mile grid located between 2,000- and 2,200-fathom contours.

Implantment commenced on 31 January. Upon reaching the implantment location, the CACTUS was prepositioned to allow for the wind/current drift factor, so that the buoy would be over the designated depth when the ground tackle was released. The actual buoy transferral from CACTUS deck to water was somewhat unsteady owing to several complications. The

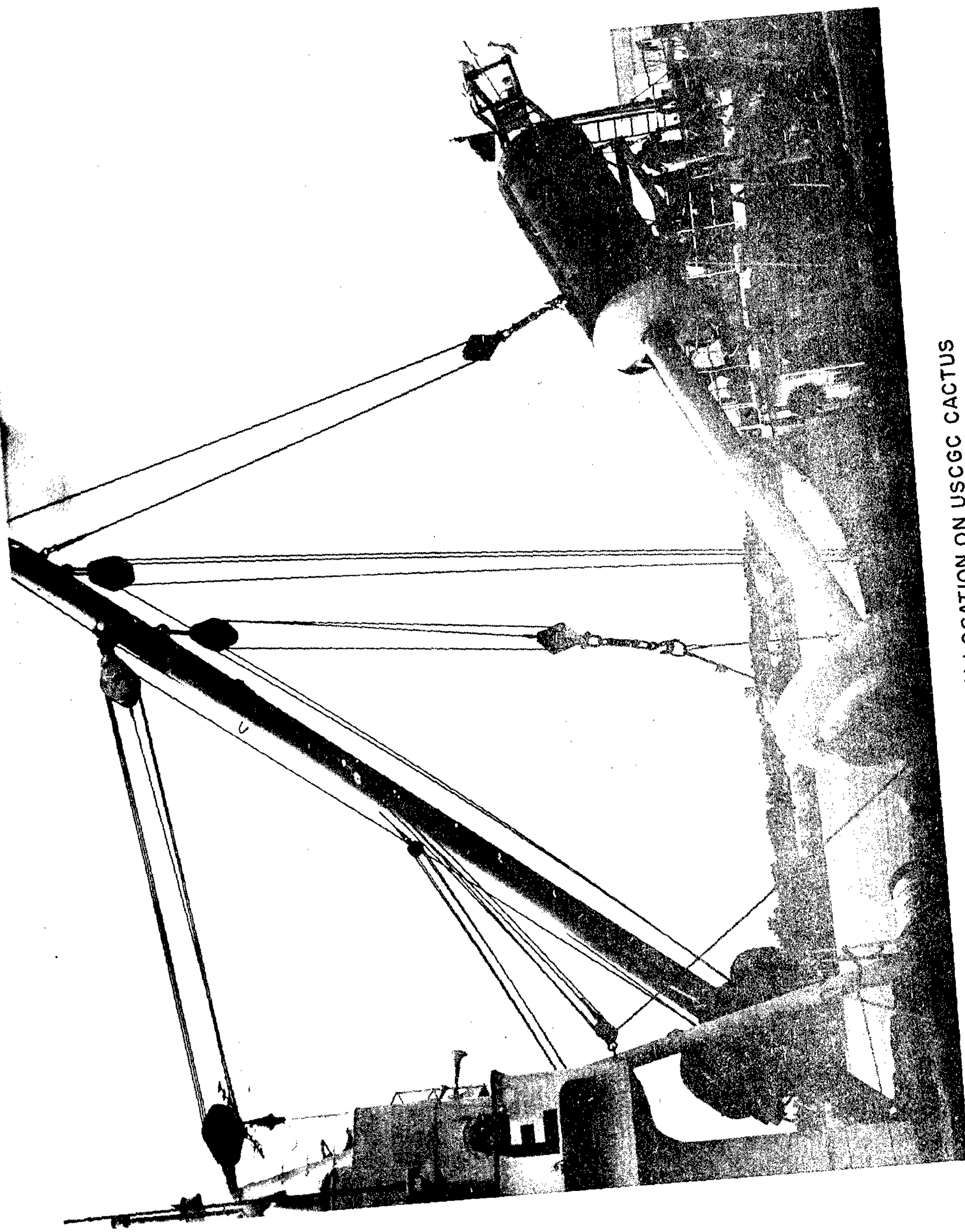

FIGURE 4 BUOY LOCATION ON USCGC CACTUS

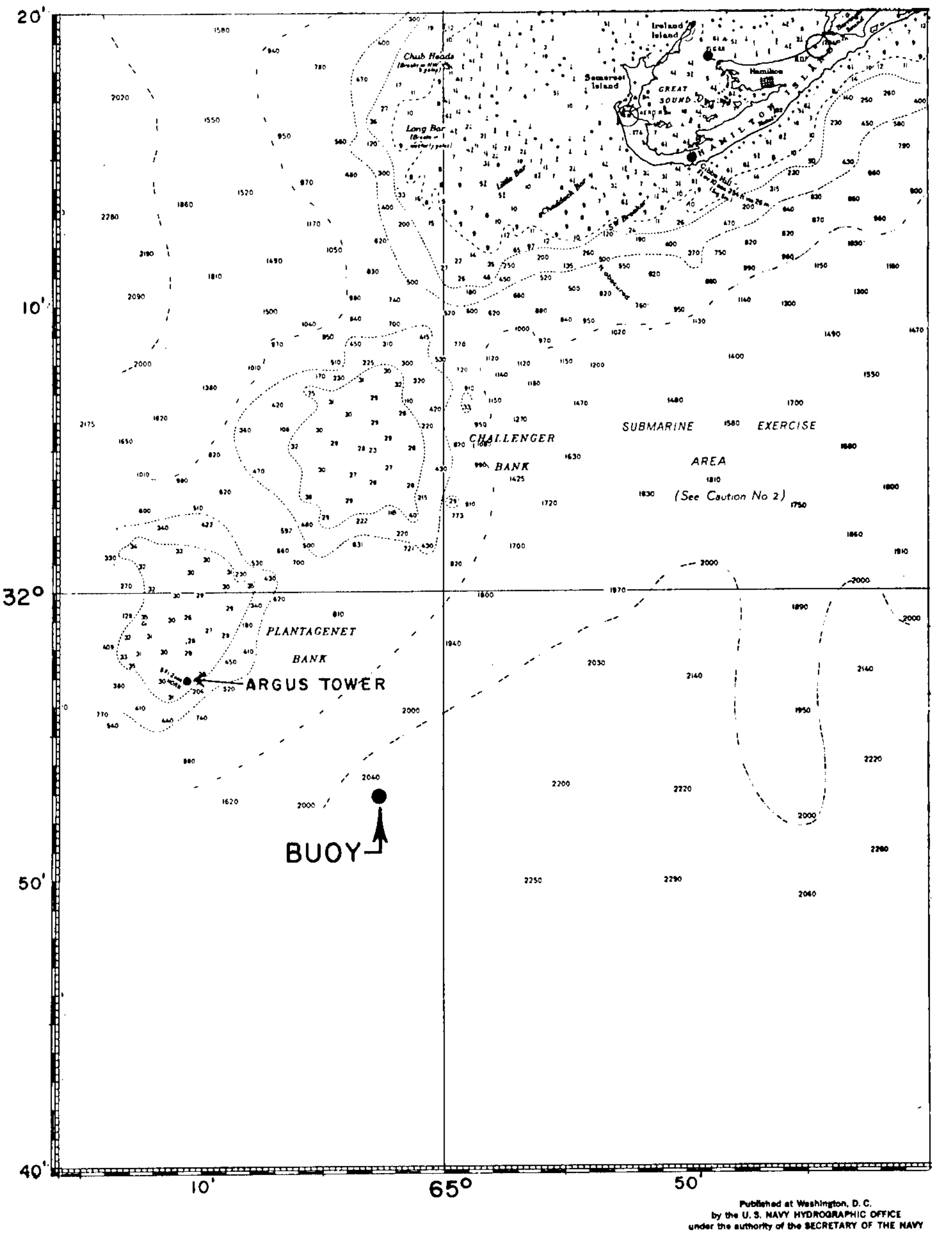

FIGURE 5 BATHYMETRIC CHART OF IMPLANTMENT AREA

remainder of the operation proceeded smoothly as sensor cable with attached floats, fish-bite cable, and the nylon mooring line were payed out while the CACTUS' small boat maintained a strain on the buoy (figure 6). After the mooring was deployed (figure 7), except for the ground tackle assembly, the distance between the CACTUS and buoy was minimized to reduce the hydrodynamic forces on the buoy during anchor freefall. Lateral motion of the buoy was not noticeable during anchor freefall. The mooring settled within a short time and was considered successful. The CACTUS remained on site for twenty-four hours to anticipate possible short-term malfunctions. Implant details are as follows:

Implant date	-	31 January 1969
Location	-	31°53'N,65°02.6'W
Range and bearing from ARGUS ISLAND Tower	-	15,500 yards, 121°
Water depth	-	12,600 feet
Transmission frequencies/ times	-	4134.75 kHz at 0540 and 1140Z 8278.25 kHz at 1740 and 2340Z
Mooring tension	-	12,250 pounds
Mooring scope	-	0.8
Maximum estimated roll (sea state 4)	-	±10° to 12°
Buoy rotation (sea state 4)	-	Approximately 2.5 radians/ minute to 270° and return

D. Retrieval

Oceanographic/meteorologic data were received at Norfolk and Washington monitoring stations until 4 February (five days after implant), when the buoy was exposed to 12- to 16-foot seas (see appendix B). The buoy broke its moor sometime between 16 February, the date of ARGUS Tower's last positive visual identification of the buoy, and 20 February, when a search aircraft could not locate the buoy.

The CACTUS located and recovered the buoy on 24 February at 31°48'N,65°10'W, approximately nine miles southeast of the implant site. Buoy recovery was conducted without incident. Post-retrieval examination revealed that (1) the sensor cable had failed near its termination in the bell-mouthed housing; (2) a subsurface battery vent hose which failed at its fitting resulted in flooding of the battery housing; (3) a circumferential weld at the interconnecting spar midsection had cracked; (4) the transmitter and data packages in the buoy body were heavily salt

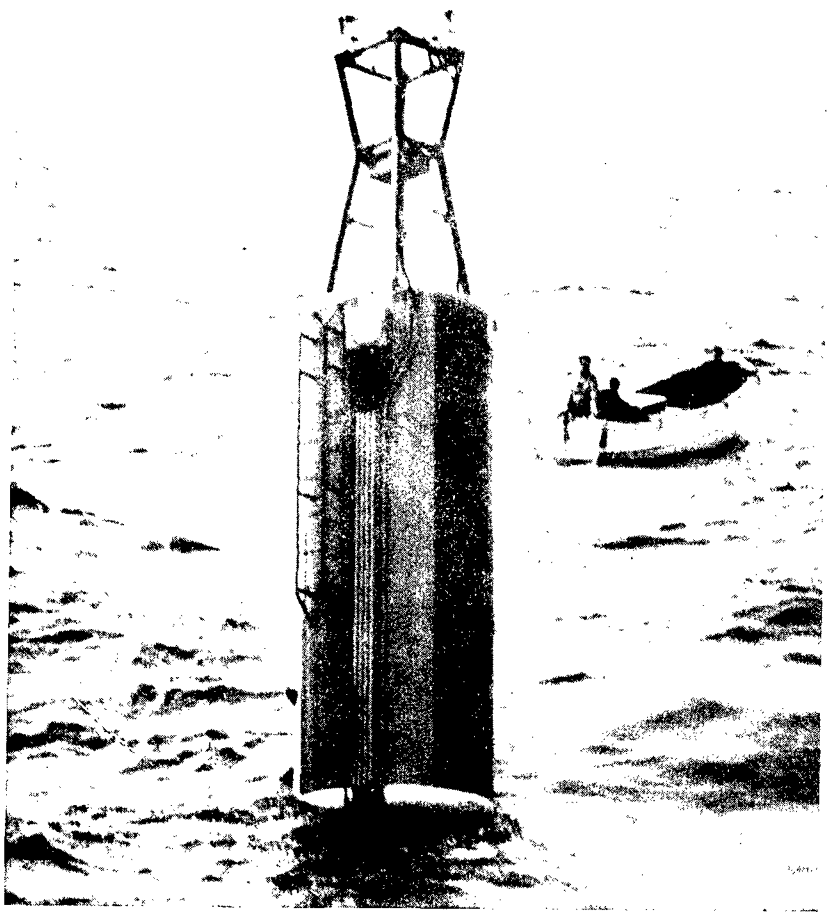

FIGURE 6 BUOY DURING IMPLANTMENT

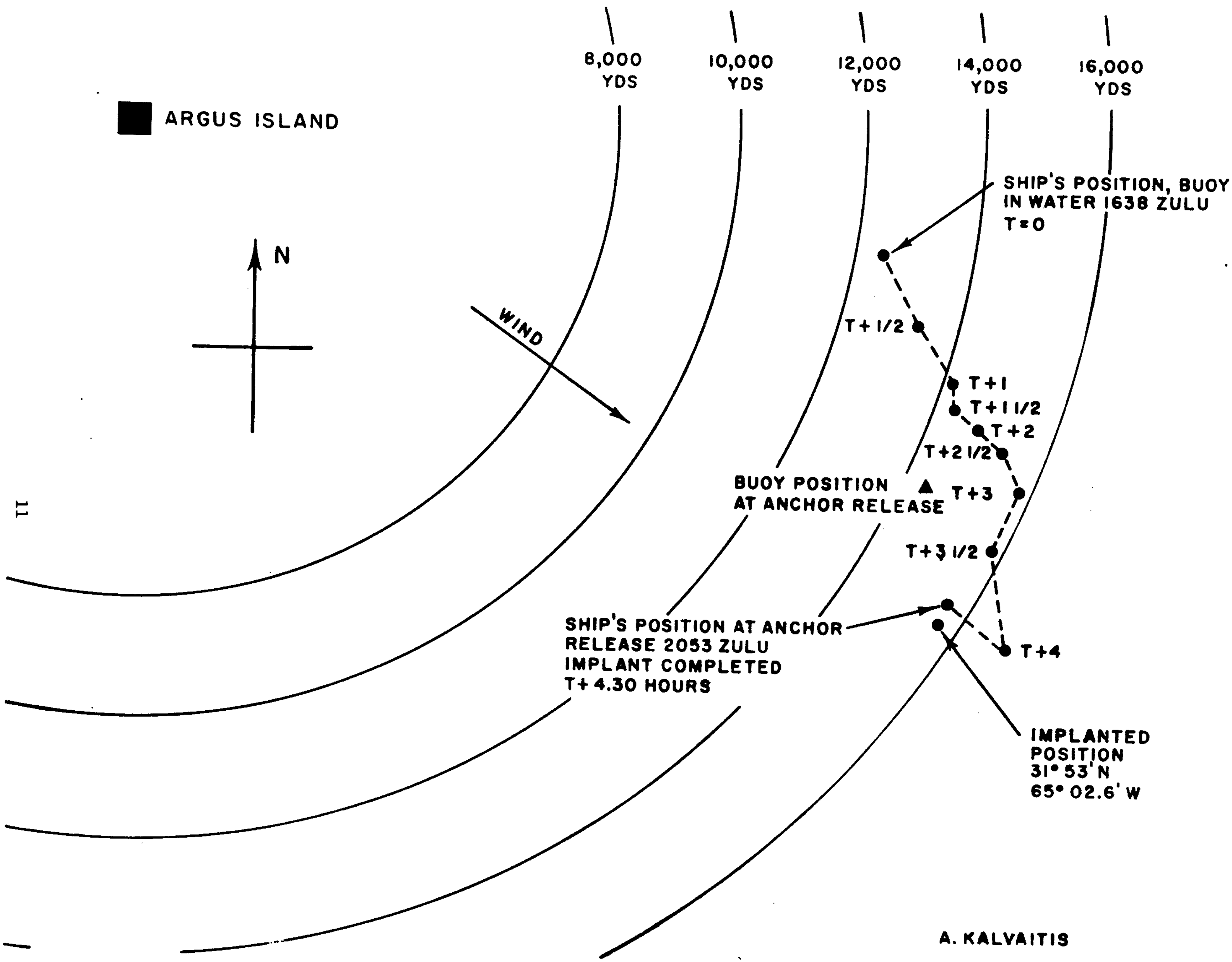

FIGURE 7 BUOY/SHIP RANGE AND BEARING WITH REFERENCE TO ARGUS ISLAND DURING IMPLANTMENT

encrusted, indicating presence of sea water; and (5) the navigational light on the buoy antenna support tower (13 feet above water level) was partially water filled.

IV. SYSTEM EVALUATION

A. Implantment and Retrieval Techniques

Experience gained during these field test operations indicates that the Litton buoy may be implanted by a Coast Guard buoy tender in relatively calm seas. The optimum handling method would use a single-point suspension, cross-deck technique with the buoy spar resting against a cushioned cradle at buoy port opening. Retrieval was accomplished by this method. The double purchase technique (2-point suspension) used during implantment resulted in transferral difficulties.

B. Transmission Range

During the 5-day transmitter operation period, the oceanographic/meteorologic data were monitored at 4134.75 kHz (0540Z and 1140Z) and 8278.25 kHz (1740Z and 2340Z) by the Naval Communications Station, Norfolk (550-mile range), and the Naval Communications Station, Washington (650-mile range). The correct transmission sequence and teletype format were followed for every transmission. In addition, reception of data during seas to 16 feet indicates that the antenna's radiation pattern was virtually unaffected by the relative motion between the antenna and its ground plane.

C. Data Accuracy and Transmission Accuracy

Since the data package calibration points shifted outside the tolerance range after implantment, data accuracy cannot be determined. Data were insufficient to determine transmission accuracy.

D. System Environmental Endurance

The buoy failed structurally in the following areas: (1) sensor cable failure near the bell-mouthed housing, (2) batteries flooded with sea water, (3) weld failure at spar midsection, and (4) data and transmitter packages salt-water damaged.

E. Ability to Remain On Station

The buoy remained on station at 31°53'N,65°02.6'W from 31 January 1969 until 16 to 20 February 1969, a period of nearly three weeks.

V. DISCUSSION

The primary purpose of this test was to evaluate the performance of a modified spar-type oceanographic/meteorologic buoy system. An important prerequisite to the evaluation was satisfaction of the 12,000- to 13,000-pound mooring tension requirements established during buoy design. Basically, tension at the buoy is directly dependent on (1) sensor and fish-bite cable weight, (2) current drag force components on buoy and moor, and (3) weight of ground tackle assembly suspended above the ocean floor. Thus, assuming a current profile and calculating buoy excursion, mooring tension is proportional to the nylon elongation characteristics. From percent ultimate breaking strength versus percent elongation curve for the nylon line, the length of mooring line required can be calculated. Post-implantment visual observations of buoy freeboard confirmed a 12,250-pound tension. The total mooring weight was less than the buoy reserve buoyancy. This safety factor prevented possible submergence of the buoy below collapse depth during anchor freefall if mooring tension were not compatible with the nylon elongation response rate characteristics.

The remainder of this discussion analyzes environmentally induced structural failures. Preliminary analysis of sensor cable failure indicated that buoy roll probably exceeded the bell-mouthed housing guide radius exit angle (figure 8). This theory is substantiated by observed rolling of approximately 10 to 12 degrees in sea state 4 (4-8 feet) one day after implantment. On several occasions prior to mooring failure, 20- to 30-foot waves were recorded at ARGUS Tower, nine miles from the buoy. Such waves could cause buoy roll exceeding 15 degrees. Because the design motion envelope indicated that maximum buoy roll would be 5 or 6 degrees, the bell-mouthed housing was designed with a 15-degree exit angle. Although the internal radius of the bell-mouthed guide is 36 inches, a one-inch radius at the lip would increase bending stresses (tensile loads) within individual cable wires when the cable overlays the bell-mouth lip. Another possible factor contributing to cable failure was Strouhal effect, that is, strumming of the buoy body and moor. Pronounced strumming was noted on the buoy after implant.

The spar midsection weld failure may be attributed to elevated bending moment tensile stresses induced by high seas. This bending moment force component is the summation of the mooring tension radial vector which is proportional to the buoy roll magnitude and the hydrodynamic forces on the buoy which are proportional to the wave height. (A remote possibility exists that the weld failure may have occurred during implantment from ship to sea). The battery vent hose failure at the battery housing located 30 feet underwater was possibly caused by high internal water particle speeds (8 feet per second in a 30-foot wave) imparting a cyclically reversing drag force acting along the exposed vent hose length. Salt deposits within the data package and transmitter indicated that salt-water leakage probably occurred through the buoy hatch gaskets. In summary, the Litton buoy was structurally inadequate from an environmental endurance standpoint. Corrective modifications would probably be relatively minor.

VI. RECOMMENDATIONS AND CONCLUSIONS

The modified spar, taut-moor buoy concept appeared valid from a design tradeoff analysis; however, this buoy test revealed several shortcomings. The structural deficiencies outlined above may be easily corrected. For

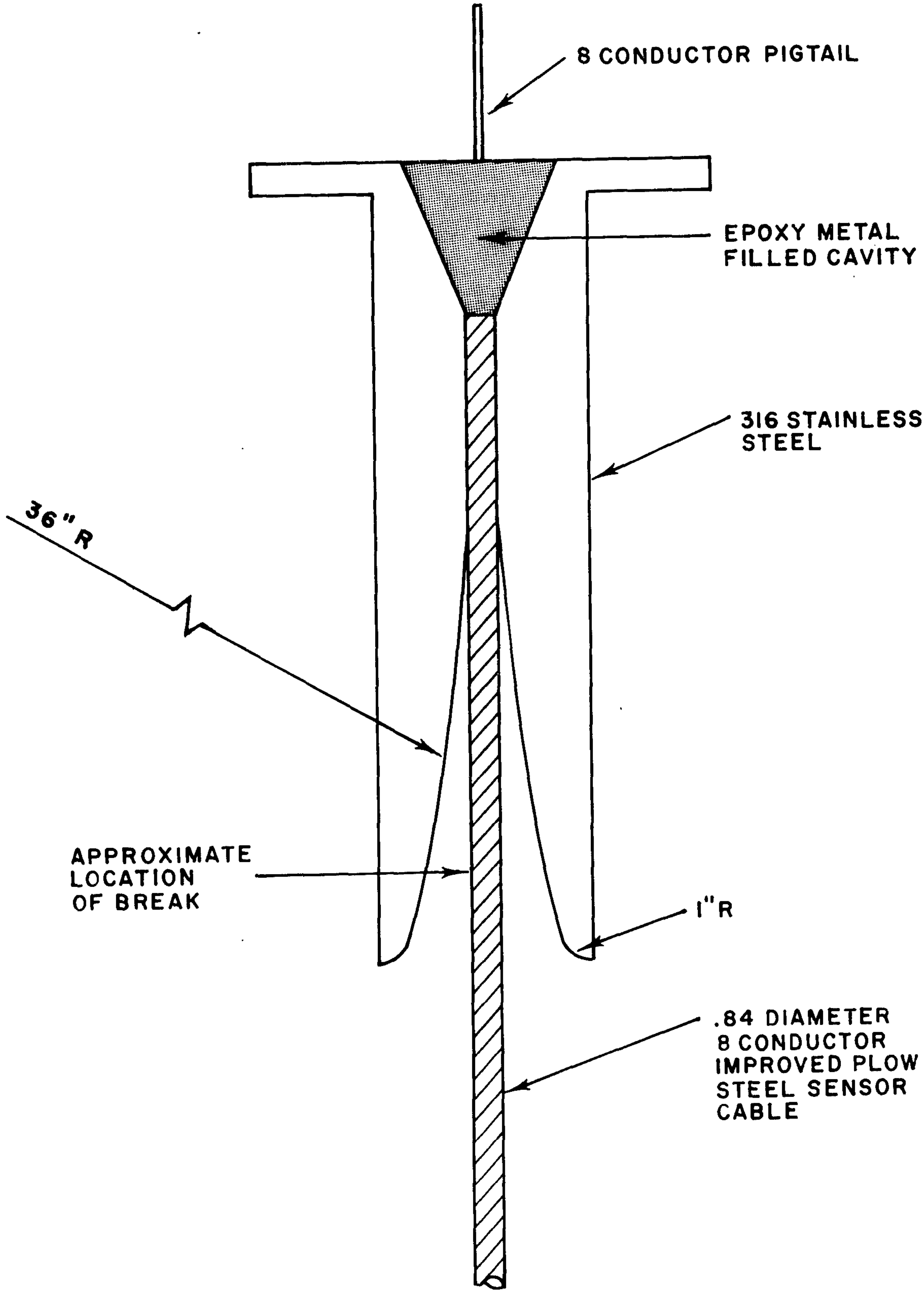

FIGURE 8 SENSOR CABLE BELL MOUTH HOUSING

example, spar strength could be doubled by increasing the skin thickness to six-sixteenths of an inch at a weight increase of 500 pounds or 5 percent. Another design recommendation would locate the protective high-pressure hose sheathing of the power cables and battery vents snugly against the buoy structure. These hoses should be housed within metal tubing throughout their length.

An additional refinement would involve use of a different power source than wet-cell batteries because of the potential explosion hazard. Salt water in the navigation light suggested that the buoy was nonresponsive to high waves and was occasionally submerged. This situation might be corrected by decreasing mooring tension, by decreasing the damping disc drag spoiler characteristics, by increasing buoyancy, or by a combination of these modifications. In addition, the buoy electronics should be contained in a watertight compartment within the buoy structure, thus offering an additional water barrier against the environment.

Historically, the weak link of most oceanographic buoys is the electromechanical interface between the oceanographic sensor cable and the buoy body. Although this body system was designed to limit dynamic mooring loads, in situ peak sensor cable load levels may only be inferred. In addition, the buoy motion envelope, specifically in the rolling attitude, was discovered to be far greater than anticipated after implantment. It is therefore difficult to offer an opinion concerning bell-mouth adequacy for this particular buoy system. Perhaps the marriage of the steel cable to a bell-mouth end termination will not function under any design configuration. NOTE: The Monster Buoy has achieved some success using nylon line and a bell-mouthed housing. Future design should incorporate a 125 bell-mouth guide radius/cable diameter ratio for stiff, high tensile strength sensor cables.

Experience gained from this buoy program may very well be applicable to future oceanographic/meteorologic platform development:

1. Proposed buoy designs should be extensively model tested. Naval architects use this technique with ships; why shouldn't buoy designers?

2. The most meaningful instrumentation on a prototype buoy and the moor should include engineering monitoring devices, such as load cells, strain gauges, accelerometers, etc. These inputs are invaluable when analyzing failures and for isolating marginal areas.

3. The buoy designer should be familiar with physical limitations of the implantment/retrieval vessel.

4. The best engineered buoy system is likely to exhibit failures initially. Buoy development involves trial-and-error methods and, consequently, an extended development program.

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APPENDIX A

DATA FORMAT

Call Sign Transmission

BES	BES	BES	BES	BES	BES	BES	BES	BES	BES
(Call Sign Letters Optionally Selectable)									
BES	BES	BES	BES	BES	BES	BES	BES	BES	BES
BES	BES	BES	BES	BES	BES	BES	BES	BES	BES

Data Transmission

Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6	Loc. 7	Loc. 8	Loc. 9	Loc. 10
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6	Loc. 7	Loc. 8	Loc. 9	Loc. 10
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6	Loc. 7	Loc. 8	Loc. 9	Loc. 10
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 11	Loc. 12	Loc. 13	Loc. 14	Loc. 15	Loc. 16	Loc. 17	Loc. 18	Loc. 19	Loc. 20
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 11	Loc. 12	Loc. 13	Loc. 14	Loc. 15	Loc. 16	Loc. 17	Loc. 18	Loc. 19	Loc. 20
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 11	Loc. 12	Loc. 13	Loc. 14	Loc. 15	Loc. 16	Loc. 17	Loc. 18	Loc. 19	Loc. 20
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$
Loc. 21	Loc. 22	Loc. 23	Loc. 24	Loc. 25	Loc. 26	Loc. 27	Loc. 28	Loc. 29	Loc. 30
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	EEE	EEE	EEE	$n_3n_2n_1$	$n_3n_2n_1$	EEE
Loc. 21	Loc. 22	Loc. 23	Loc. 24	Loc. 25	Loc. 26	Loc. 27	Loc. 28	Loc. 29	Loc. 30
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	EEE	EEE	EEE	$n_3n_2n_1$	$n_3n_2n_1$	EEE
Loc. 21	Loc. 22	Loc. 23	Loc. 24	Loc. 25	Loc. 26	Loc. 27	Loc. 28	Loc. 29	Loc. 30
$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	$n_3n_2n_1$	EEE	EEE	EEE	$n_3n_2n_1$	$n_3n_2n_1$	EEE
Loc. 31	Loc. 32	Loc. 33	Loc. 34	Loc. 35	Loc. 36	Loc. 37	Loc. 38	Loc. 39	Loc. 40
EEY	$n_3n_2n_1$	$n_3n_2n_1$	ZFY	BBS	SSS	$n_3n_2n_1$	$n_3n_2n_1$		
Loc. 31	Loc. 32	Loc. 33	Loc. 34	Loc. 35	Loc. 36	Loc. 37	Loc. 38	Loc. 39	Loc. 40
EEY	$n_3n_2n_1$	$n_3n_2n_1$	ZFY	BBS	SSS	$n_3n_2n_1$	$n_3n_2n_1$		
Loc. 31	Loc. 32	Loc. 33	Loc. 34	Loc. 35	Loc. 36	Loc. 37	Loc. 38	Loc. 39	Loc. 40
EEY	$n_3n_2n_1$	$n_3n_2n_1$	ZFY	BBS	SSS	$n_3n_2n_1$	$n_3n_2n_1$		

Detailed Data Format

_____ Indicates Space

Data Numerical Value vs. Data Printout

0	E
1	Z
2	D
3	B
4	S
5	Y
6	F
7	X
8	A
9	W

Data Format Location vs. Sensor Type/Location

1	Water Temperature	-	0 ft. depth
2	" "	-	20 ft. "
3	" "	-	40 ft. "
4	" "	-	60 ft. "
5	" "	-	80 ft. "
6	" "	-	100 ft. "
7	" "	-	140 ft. "
8	" "	-	180 ft. "
9	" "	-	220 ft. "
10	" "	-	260 ft. "
11	" "	-	300 ft. "
12	" "	-	340 ft. "
13	" "	-	380 ft. "
14	" "	-	420 ft. "
15	" "	-	460 ft. "
16	" "	-	500 ft. "
17	" "	-	540 ft. "
18	" "	-	580 ft. "
19	" "	-	620 ft. "
20	" "	-	660 ft. "
21	" "	-	700 ft. "
22	" "	-	800 ft. "
23	" "	-	900 ft. "
24	" "	-	1000 ft. "
25	Water Pressure	-	100 ft. "
26	" "	-	500 ft. "
27	" "	-	1000 ft. "

Data Format Location vs. Sensor Type/Location

28	Barometric Pressure
29	Air Temperature
30	Wind Speed
31	Wind Direction
32	Battery Voltage
33	Buoy Temperature
34	Calibration Point - Water Temperature
35	Calibration Point - Air Temperature
36	Calibration Point - Water Pressure
37	RF Forward Power
38	RF Reverse Power
39	Spare
40	Spare

Scale Factors to be Applied to Data Printout

Locations 1-24, 34: Water Temperature $= \frac{N - 10}{10}$ ^oC

Locations 25-27, 36: Water Pressure $= \frac{N}{2}$ psi

Location 28: Barometric Pressure $= 950 + \frac{N}{10}$ millibars

Locations 29, 33, 35: Temperature $= \frac{N - 120}{10}$ ^oC

Location 30: Wind Speed $= \frac{N}{10}$ knots

Location 31: Wind Direction = N^o with respect to magnetic north

Location 32: Battery Voltage $= \frac{N}{10}$ volts

Location 37: Forward Power $= \frac{N}{2}$ watts

Location 38: Reverse Power $= \frac{N}{10}$ watts

APPENDIX B

ARGUS TOWER METEOROLOGIC DATA

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ARGUS TOWER METEOROLOGIC DATA

DATE	WIND DIRECTION	WIND SPEED	WAVE HEIGHT
1 February	360°	10 kts.	5-9 ft.
2 February	250°	15 kts.	4-6 ft.
3 February	250°	15-20 kts.	5-8 ft.
4 February	290°	30 kts.	12-16 ft.
5 February	260°	30 kts.	15-20 ft.
6 February	240°	10-15 kts.	10-16 ft.
7 February	230°	25 kts.	8-14 ft.
8 February	360°	15 kts.	7-12 ft.
9 February	170°	45-50 kts.	12-13 ft.
10 February	250°	40-45 kts.	25-30 ft.
11 February	290°	30-35 kts.	15-20 ft.
12 February	200°	25 kts.	8-10 ft.
13 February	260°	10-15 kts.	8-10 ft.
14 February	300°	25-30 kts.	8-10 ft.
15 February	280°	12-18 kts.	10-12 ft.
16 February	150°	12 kts.	14-16 ft.
17 February	230°	18 kts.	9-12 ft.
18 February	260°	25-30 kts.	10-12 ft.
19 February	260°	45-50 kts.	18-22 ft.
20 February	275°	40-45 kts.	18-22 ft.
21 February	330°	15 kts.	12-14 ft.
22 February	020°	20-25 kts.	10-12 ft.
23 February	030°	12-18 kts.	8-10 ft.
24 February	180°	15-20 kts.	6-8 ft.

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13. ABSTRACT

This report discusses the sea test and evaluation of a modified spar, taut-moored oceanographic/meteorologic buoy. The Litton buoy was implanted during January 1969 in 12,600 feet of water approximately twenty-five miles southwest of Bermuda. This test was terminated after three weeks when the buoy parted its moor at the sensor cable bell-mouthed housing. Detailed information covers implantment and retrieval techniques, environmental endurance, and overall system effectiveness. The major buoy structural deficiencies are documented and analyzed. Although the taut-moored concept shows promise, failure of the oceanographic sensor cable end termination remains a formidable problem.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
BUOYS Spar Buoys						
DATA TRANSMISSION SYSTEMS						
EXPERIMENTAL DATA						
INSTRUMENTATION						
METEOROLOGY Weather Stations						
OCEANOGRAPHIC DATA Telemetering Buoy Data						
OCEANOGRAPHIC EQUIPMENT Oceanographic Platforms						
OCEANOGRAPHY						
OCEANOLOGY						
OCEANS						
SEA WATER						
WATER WAVES Ocean Waves						

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